Enhanced Bomb Effects For Obstacle Clearance - Analysis

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LONG TERM GOALS

The Navy has identified the need for a system capable of simultaneously breaching obstacles and clearing mines, in-stride, from over the horizon, during an amphibious assault. In response to the obstacle-breaching concern, the Enhanced Bomb Effects for Obstacle Clearance program was started. The purpose of the Naval Surface Warfare Center, Dahlgren Division (NSWCDD)/Coastal Systems Station (CSS) Bomb Effects program is to study and identify the damage mechanisms of obstacles (on land and in water) subjected to multiple bomb detonations. This knowledge will then provide the acquisition community with the technology for development of an obstacle clearance system.

OBJECTIVES

Standard general purpose (GP) bombs represent an existing, rapidly deployable, building block for developing an effective system against obstacles. In order to expand the existing knowledge base on the effectiveness of these weapons against obstacles, an analytical effort was launched to complement the experimental efforts being performed by NSWCDD/CSS.

The objective of this effort is to generate semi-analytic/empirical models that, when incorporated in system effectiveness studies, will determine the lethality of GP bombs against tetrahedron obstacles in a variety of scenarios. These models will be applicable in both air and water environments, and will account for bomb size, explosive type, ground effects, case confinement, multiple bomb effects, including simultaneous and sequential detonation, and cumulative damage. In general, two analytic models will be developed, the Bomb Output Model and the Obstacle Response Model. These two

models will be combined into, and linked within, what is being called the BombFX code. The output of this code will be in a form that can be implemented in the Monte Carlo Obstacle Clearance (OBSCLR) Code to estimate the number of bombs necessary to clear a band of obstacles on the beach or in the surf zone.

APPROACH

Using data collected from previous field tests, analytic models were developed to characterize the output and subsequent damage to targets in air from Mk 82 and Mk 83 bombs. These models were incorporated into the BombFX code in FY99. In FY 00, a similar approach to modeling the response of underwater obstacles to Mk 82 bombs was followed. One-twelfth (1/12) scale model tests were conducted at SRI to assist in quantifying damage from the Mk82 bomb at several standoffs. The potential damage from a simultaneous detonation of a line of bombs was also evaluated at this scale. Work has been done with several hydrocodes to validate the BombFX results for simultaneous detonations and to help prepare instrumentation for the full-scale test performed by NSWC/CSS at Eglin Air Force Base.

WORK COMPLETED

Validation of BombFX Analysis Tool. In FY99, the blast characterization models and an obstacle damage model were implemented into, and linked within, the BombFX analysis tool. In FY00, several areas of functionality were added to the BombFX application, including the ability to scale to different sized explosive charges, the ability to select among nine different explosive compositions, the ability to predict in water as well as air, and the ability to account for the effects of a ground surface and case confinement for air blast. Part of the FY 00 effort was put towards validating the BombFX code results. The BombFX models were derived in part from hydrocode analysis for a single bomb. The effect of multiple bombs simultaneously detonating was calculated internally to the BombFX code with a superposition scheme. Several hydrocodes, including the Dynamic System Mechanics Advanced Simulation (DYSMAS) code, CTH and MESA; were used to analyze the output of two bombs simultaneously detonated. The results of all the analyses were compiled and compared.

Obstacle Response Analytical Effort. The obstacle response analytical effort concentrated on the modeling and characterization of the response of steel tetrahedron obstacles to the explosive loading from Mk 80 series bombs. The DYSMAS hydrocode is particularly suited for determining the loading function since the coupled Eulerian/Lagrangian mesh allows the fluid-structure interaction to be evaluated, which includes the significance of reflected shocks. Tests were conducted at SRI using a single 50-gram charge against 1/12-scale obstacles with different orientations relative to the charge. The deflection of the legs suggested that those legs nearest the charge might be shielding the farthest legs. Analyses using the DYSMAS hydrocode indicated some shielding, but it was a second order effect. It was found that the large deformation of legs closest to the charge was primarily due to the fact that the pressure is significantly higher. Initially we conducted an analysis of a single leg to simplify calculations so that we could investigate scaling, strain-rate effects, orientation of the leg cross-section to the shock and the pressure loading. The results were as follows:

- Hopkinson (cube root) scaling of the charge applies when scaling up the model deformation to the full scale.

- The higher strain rate of the model resulted in deflections and strains in the model that were slightly lower than those in the full scale.

- The legs of the tetrahedron have an angle cross-section. The deformation is somewhat higher when the angle is open in relation to the shock wave than when the angle is closed.

- The coupled DYSMAS analysis accounting for fluid-structure interaction resulted in larger deformation than when just hydrodynamic loading $C_d q$ was applied.
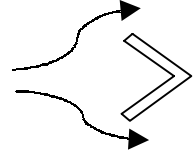
A 3-D coupled analysis of a full-up tetrahedron using DYSMAS resulted in excessive run time. Therefore, we conducted a DYNA3D analysis prescribing the pressure load based on the findings from the analysis of a single leg. The hydrodynamic loading $C_d q$ was increased to approximate the effect of reflected shocks. The resulting deformations, shown in Figure 1, were in reasonable agreement with model tests considering the complexity of the open frame structure.
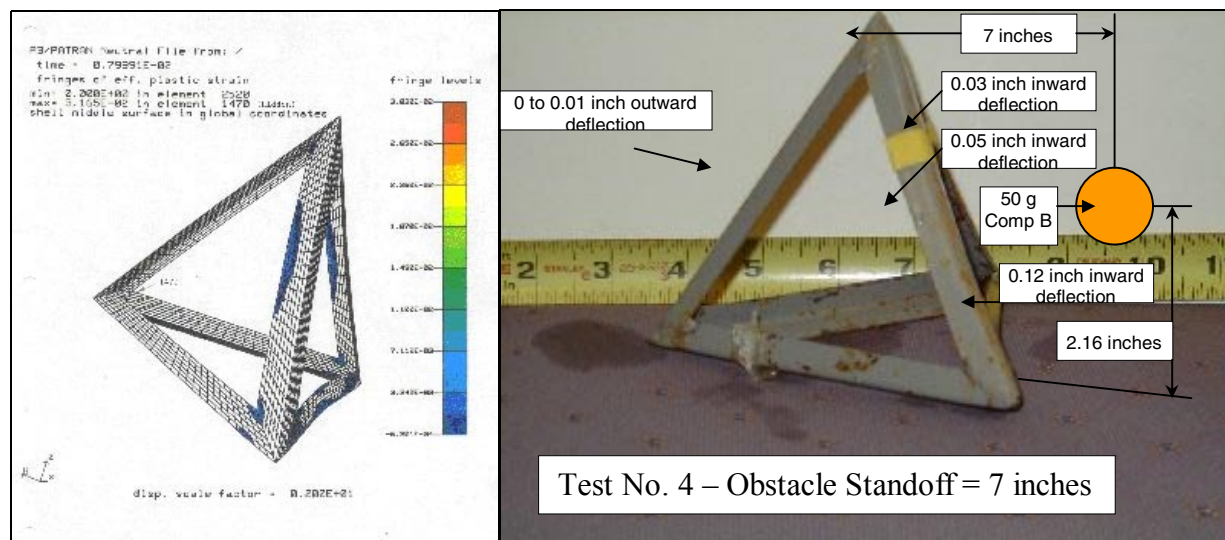

Figure 1. Obstacle Response Comparison

Field tests of MK 82, MK 83, and MK 84 bombs against tetrahedron obstacles indicate failure occurs in the welded joints. We therefore used the full-up DYNA3D model to construct an isodamage pressure-impulse curve to cause a prescribed level of strain in the welded joints. Knowing the pressure and impulse developed by 190 pounds of Comp B, an estimate of the lethal radius was made. The isodamage curve was then used to assess the potential increase in lethal area by simultaneous detonation of multiple bombs.

Explosive Output Analytical Effort. The remaining work for FY00 was put towards characterizing the output for multiple charges simultaneously detonated underwater. Three distinct models were developed. The first model explicitly modeled two 50-gram spherical charges. The pressure and impulse from pressure resulting from the simultaneous detonation was calculated. Those results were plotted against isodamage curves developed in the Obstacle Response Analytical Effort to produce areas within which lethal damage would be imposed on any obstacle. These results were then evaluated

to determine the "optimum" spacing of the charges based on a particular lethal radius. By simultaneous detonation of the two bombs the theoretical lethal area was increased by 24.5% as illustrated in Figure 2.
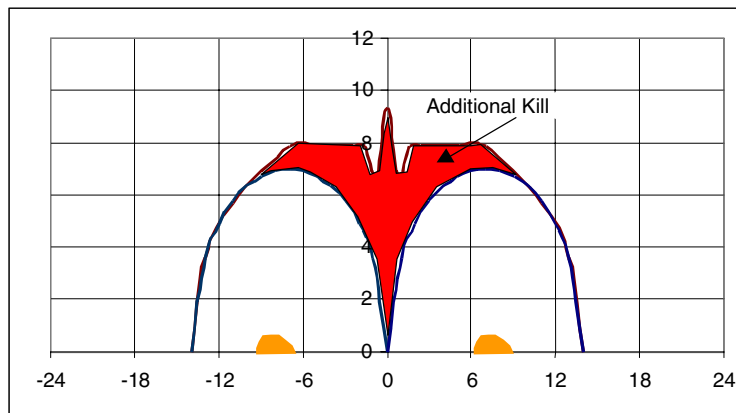

Figure 2. Increased Lethal Area

The second model used available symmetry to model an infinite line of distinct 50-gram spherical charges. Results of this model were compared to the previous model to determine what enhancement (if any) a line of charges would produce over that of two charges. Also, this analysis was used to determine whether the first model, which is larger and more cumbersome to use, could be replaced, thereby saving run time in future analysis. This model was also used to evaluate the effects of the sand bottom using the P-alpha model in DYSMAS.

The third model was developed to examine an array of seven 50-gram spherical charges arranged in a hexagonal pattern. The array has three lines of charges (two lines of two charges and a center line of three charges) with the centers of the charges being offset from adjacent lines. Due to the unique symmetry conditions of the laydown, CTH, which has more flexible grid geometry, was used to examine this geometry.

Sub-Scale Testing. A program of sub-scale testing was undertaken to reduce costs while obtaining data for comparison to models. SRI conducted the tests under the direction of Paul Gefken. Four tests were completed for the task. Each test was instrumented with pressure gauges and included between four and seven obstacles. The first test utilized a single charge to evaluate the damage to the 1/12-scale obstacle models at various standoffs. Results of this test established the lethal radius for the obstacle. Two charges, placed at their optimum separation as determined in the Explosive Output Analytical Effort, were used in the second test. The second test was repeated in a tank partially filled with sand in order to evaluate the effect of the bottom on damage. The fourth test was set-up to evaluate the effectiveness of a seven-charge array. The array was defined using a tactically practical arrangement and spacing according to the previously defined optimum spacing. Two additional tests will be conducted to further study the matrix application.

RESULTS

The analytical efforts resulted in several significant developments and/or findings as summarized below:

- Hydrocode results are in reasonable agreement with in-water sub-scale test results.

- Sand saturation in the SRI test pool is such that modeling of the sand is unnecessary for that application.

- Regardless of the number of charges in a line (two or more) the peak pressure in the field is unchanged. However, the total impulse at any point in the field can be doubled due to the influence of additional charges.

- Optimum spacing for two charges is the same as that for a line of charges.

- Optimum spacing for charges in a line (two or more) is only slightly larger than twice the lethal radius.

- Significant increases in impulse at a point interior to the array of seven charges may provide larger optimum separation between charges.

- Damage to sub-scale obstacles is indicative of damage to full-scale obstacles. However, sub-scale obstacles were specifically made with high-quality welds to inhibit weld failure. Strains near the weld are indicative of sufficient strain at full scale to cause weld failure.

IMPACT/APPLICATIONS

The capability to calculate pressure, impulse and energy from in-air and/or underwater explosions coupled with the capability to compute the dynamic response of the obstacle will allow computation of lethal radii of GP bombs. This capability will permit analytical estimates of the number of bombs/aircraft sorties to clear obstacles in a given tactical scenario. Such a capability would ultimately be used to plan a tactical concept of operations during an amphibious assault. PMS-407 is expected to perform an Analysis of Alternatives (AOA) in 2003. This task will provide important input into that analysis for comparison of GP bombs to other alternatives.

TRANSITIONS

The analytic models will be transitioned to NSWC/CSS and PMS-407 to allow the effectiveness of GP bombs in obstacle clearance to be evaluated.

RELATED PROJECTS

This project exploits and builds on test data obtained from ongoing 6.4 and 6.5 mine and obstacle breaching programs; specifically Mk 83 tests from Obstacle Breaching Program and SABRE testing. The Standoff Delivery effort is helping define the limits of bomb verticality that are achievable and this will impact some of the planned testing and modeling efforts.

REFERENCES

J.E. Goeller, 1999. Effectiveness of MK 80 Series General Purpose Bombs Against a Tetrahedron Beach Obstacle, Advanced Technology & Research (ATR) Corporation Report No. FP-019, August.

J.B. Conant, 1946. Effects of Impact and Explosion, National Defense Research Committee, Vol 1, Washington, D.C.

U. Fano, 1945. Methods for Computing Data on the Terminal Ballistics of Bombs, Estimation of the Air Blast, Report 524, BRL, February.

M.M. Swisdak, 1975. Explosion Effects and Properties, Part I, - Explosion Effects in Air, NSWC/WOL/TR 75-116, October.

J.M. Carson, 1984. Conventional High-Explosive Blast and Shock (CHEBS) Series: Mark-82 General Purpose Bomb Tests, Air Force Weapons Laboratory, AFWL-TR-84-27, June.